EARTH GRIDDING

VISIBLE/INFRARED IMAGER/RADIOMETER SUITE ALGORITHM THEORETICAL BASIS DOCUMENT

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GLOSSARY OF ACRONYMS

ATBD	Algorithm Theoretical Basis Document
BRDF	Bi-directional Reflectance Distribution Function
CDR	Critical Design Review
CMIS	Conical-Scanning Microwave Imager/Sounder
CrIS	Cross-track Infrared Sounder
DPA	Data Processing Architecture
DoD	Department of Defense
EDR	Environmental Data Record
GDSR	Gridded Daily Surface Reflectance
GMBT	Gridded Monthly Brightness Temperature
GMSR	Gridded Monthly Surface Reflectance
GMVI	Gridded Monthly Vegetation Index
GSA	Gridded Surface Albedo
GWSR	Gridded Weekly Surface Reflectance
HSR	Horizontal Spatial Resolution
ID	Identification Number
IP	Intermediate Product
MNSR	Monthly Non-snow Surface Reflectance
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	Net Primary Productivity
OMPS	Ozone Mapping and Profiler Suite
PSN	Net Photosynthesis
RDR	Raw Data Record
SBRS	Santa Barbara Remote Sensing
SDR	Sensor Data Record
SNR	Signal-to-Noise Ratio
SRD	Sensor Requirements Document
SASA1	Surface Albedo Sub-Algorithm 1
TOA	Top of Atmosphere
VIIRS	Visible/Infrared Imager/Radiometer Suite
WVI	Weekly Vegetation Index

ABSTRACT

Most of the Visible/Infrared Imager/Radiometer Suite (VIIRS) Environmental Data Record (EDR) algorithms will require as input one or more types of auxiliary-ancillary data. In most cases the auxiliary-ancillary data are obtained from sources that are independent of the National Polar-orbiting Operational Environmental Satellite System (NPOESS). In some cases recent VIIRS retrievals are required and co-located Conical-Scanning Microwave Imager/Sounder (CMIS), Cross-track Infrared Sounder (CrIS), and Ozone Mapping and Profiler Suite (OMPS) data are desirable. These data will generally not be reported at the current VIIRS pixel locations but rather will be reported at some fixed Earth grid locations or some instrument specific pixel locations in the VIIRS pixel neighborhood.

This document describes the mapping and gridding that will be performed within the VIIRS Data Processing Architecture (DPA) in support of the EDR generation algorithms. The approach presented provides a computational efficient solution that will result in all information needed for the EDR algorithms to match auxiliary-ancillary and other NPOESS data to the VIIRS observations.

1.0 INTRODUCTION

1.1 PURPOSE

This Algorithm Theoretical Basis Document (ATBD) describes the algorithms to re-grid auxiliary-ancillary data and to grid VIIRS Sensor Data Record (SDR), Intermediate Product (IP), and Environmental Data Record (EDR) data. This document describes the required inputs, the theoretical description of the re-gridding and gridding algorithms, practical considerations for post-launch implementation, and the assumptions and limitations associated with these algorithms.

This ATBD is part of the VIIRS Algorithm Subsystem's documentation hierarchy as called for in the VIIRS Software Development Plan *[V-1]* (see Section 1.4, VIIRS Documents). As shown in Figure 1 the Algorithm Subsystem Specification is the controlling document for this ATBD. The software architecture for implementing the re-gridding and gridding algorithms is documented separately.

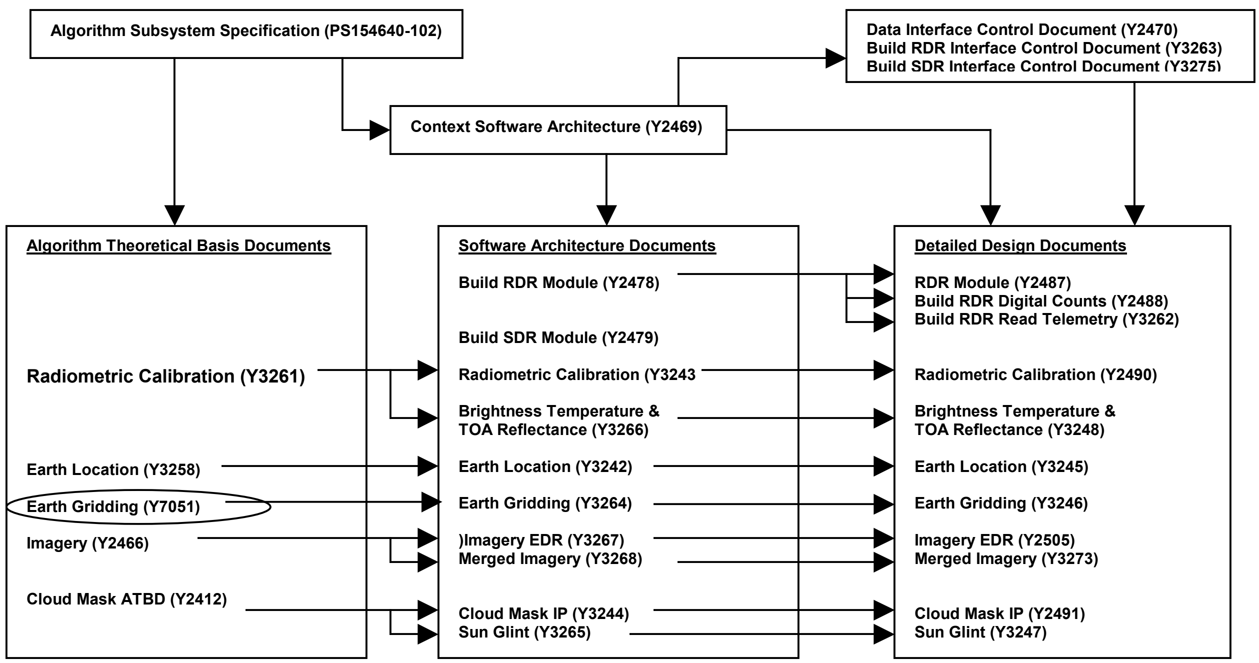

Figure 1. Hierarchy of VIIRS documents that relate to the design of the re-gridding and gridding software (this ATBD is circled)

1.2 SCOPE

This document covers the algorithm theoretical basis for operational re-gridding and gridding. There are no gridded EDR deliverables in the VIIRS Sensor Requirements Document (SRD) *[V-2]* (see Section 1.4, VIIRS Documents). Therefore discussion will be limited to the gridding needed to support the generation of EDR swath products including the production of gridded IPs. The algorithms documented herein could be adapted to the production of gridded EDR products if such a requirement develops at a future date.

This section describes the purpose and scope of this document; it also includes a listing of VIIRS documents that will be cited in the following sections. Section 2 provides a brief overview of the objectives of the re-gridding and gridding and the strategy for the operational algorithms. Section 3 contains the essence of this document—a complete description of the re-gridding and gridding algorithms. Consideration is given to the overall structure, the required inputs, a description of the products, and practical implementation issues. Section 4 contains a listing of non-VIIRS references that are cited throughout this document.

1.3 DEFINITIONS

The following definitions are relevant to this ATBD:

<u>Auxiliary-Ancillary Data</u>

Those non-VIIRS data required by the EDR algorithms as identified in the VIIRS Interface Control Document *[V-3]* (see Section 1.4, VIIRS Documents) are the auxiliary-ancillary data.

<u>Gridding</u>

Gridding is the process of accumulating VIIRS pixel data into grid cells on an Earth model then combining these data through data selection, weighting, interpolation, and averaging to a single value per grid cell that is representative of the retrieval at that location or area during a specific time period.

<u>Re-gridding</u>

Re-gridding is the process of referencing auxiliary-ancillary data to the VIIRS pixel data. Auxiliary-ancillary data may be representative of locations or areas on a fixed grid or may be representative of points on the surface of the Earth that are not uniformly distributed. Typically the distribution of each auxiliary-ancillary data type will be much coarser than the spacing between the centers of VIIRS pixels.

1.4 VIIRS DOCUMENTS

Reference to other VIIRS documents within this ATBD will be indicated by an italicized number in brackets, e.g., *[V-1]*.

[V-1] VIIRS Software Development Plan (SBRS Doc. Y2388)

[V-2] NPOESS IPO, 1997, Visible/Infrared Imager/Radiometer Suite (VIIRS), Sensor Requirement Document (SRD), Prepared by Associate Directorate for Acquisition, NPOESS Integrated Program Office.

[V-3] VIIRS Data Interface Control Document (SBRS Doc. Y2470)

[V-4] VIIRS Earth Location ATBD (SBRS Doc. Y3258)

[V-5] VIIRS Context Software Architecture (SBRS Doc. Y2469))

[V-6] VIIRS Earth Gridding Software Architecture (SBRS Doc. Y3243)

[V-7] Performance Specification Algorithm Specification for the VIIRS (PRF PS154640-102)

1.5 REVISIONS

Version 4.0 is the first working version of this document. It is dated May 2001. There were no versions numbered 1.0 , 2.0, or 3.0. This version number was selected to match the delivery of the previously existing VIIRS ATBDs, most of which had undergone three previous version releases.

The next version (Version 5.0) will be part of the deliverables for Critical Design Review (CDR). The Version 5.0 document will be a complete description of all the re-gridding and gridding algorithms that are introduced in this version as well as any changes identified during the software detailed design.

2.0 EXPERIMENT OVERVIEW

2.1 OBJECTIVES OF EARTH GRIDDING

Each EDR (except Imagery) requires some type of re-gridded and/or gridded data input for operational processing. Because of the 20 minute per orbit processing time constraint placed on the VIIRS algorithm subsystem the re-gridding and gridding schemes must be capable of co-locating the needed data to the VIIRS pixel locations in a highly efficient way.

2.2 INSTRUMENT CHARACTERISTICS

A VIIRS will be carried aboard each platform of the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS is a joint mission between the Department of Defense (DoD), the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). The VIIRS is a single visible/infrared sensor capable of satisfying the needs of all three communities, as well as the general research community. As such, the VIIRS will have three key attributes: high spatial resolution with controlled growth off nadir, low production and operational cost, and a large number of spectral bands to satisfy the requirements for generating accurate operational and scientific products. The nominal altitude for an NPOESS satellite will be 833 km. The VIIRS scan will extend to 56 degrees on either side of nadir.

The VIIRS SRD places explicit requirements on spatial resolution for the Imagery EDR. Specifically, the horizontal spatial resolution (HSR) of bands used to meet threshold Imagery EDR requirements must be no greater than 400 m at nadir and 800 m at the edge of the scan. This led to the development of a unique scanning approach which optimizes both spatial resolution and signal to noise ratio (SNR) across the scan. The concept is summarized in Figure 2 for the imagery bands; the nested lower resolution radiometric bands follow the same approach at exactly twice the size. The VIIRS detectors are rectangular, with the smaller dimension projecting along the scan. At nadir, three detector footprints are aggregated to form a single VIIRS "pixel." Moving along the scan away from nadir, the detector footprints become larger both along track and along scan, due to geometric effects and the curvature of the Earth. The effects are much larger along scan. At around 32 degrees in scan angle, the aggregation scheme is changed from 3x1 to 2x1. A similar switch from 2x1 to 1x1 aggregation occurs at 48 degrees. The VIIRS scan consequently exhibits a pixel growth factor of only 2 both along track and along scan, compared with a growth factor of 6 along scan which would be realized without the use of the aggregation scheme.

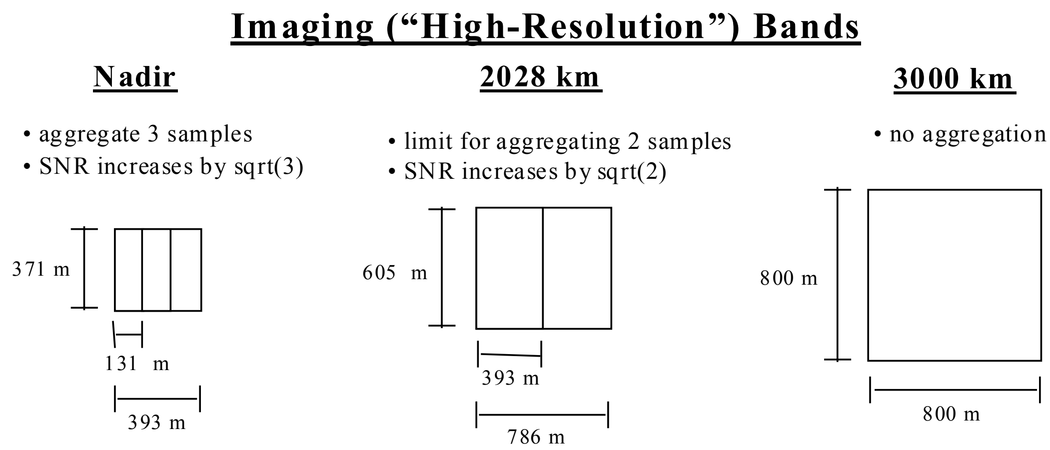

Figure 2. VIIRS detector footprint aggregation scheme for building "pixels."

2.3 EARTH GRIDDING STRATEGY

Earth gridding includes two distinct processes: gridding and re-gridding.

Gridding is the process of accumulating VIIRS pixel data into grid cells on an Earth model then combining these data through data selection, weighting, interpolation, and averaging to a single value per grid cell that is representative of the retrieval at that location or area during a specific time period.

Re-gridding is a process of referencing auxiliary-ancillary data to the VIIRS pixel data. Auxiliary-ancillary data may be representative of locations or areas on a fixed grid or may be representative of points on the surface of the Earth that are not uniformly distributed. In general the distribution of each auxiliary-ancillary data type will be much coarser than the spacing between the centers of VIIRS pixels. Exceptions are the digital elevation model (DEM) and the land-sea mask, which will be processed by the Geolocation module *[V-4]*. Therefore this ATBD will be limited to the re-gridding of coarser resolution auxiliary-ancillary data.

There is some commonality in these processes however the position in the process sequence differs. Commonalities include the Earth model on which each will be based and the technique for mapping data to this model. Most re-gridding will be a pre-processing activity that will be performed whenever the location of an auxiliary-ancillary data type changes. The locations of some types of auxiliary-ancillary data will never change so re-gridding will only be needed once.. Gridding is a post EDR production process.

3.0 ALGORITHM DESCRIPTION

3.1 PROCESSING OUTLINE

Re-gridding and gridding will be performed at various times relative to the operational processing. Some will be done as pre-processing steps prior to receipt of mission data, some will be performed during the processing of mission data, and some will be performed during post-EDR processing.

In general all auxiliary-ancillary data will be pre-processed except for the DEM, the land-water mask, the Spectral Library, and Extraterrestrial Solar Irradiances. This pre-processing will map each auxiliary-ancillary data type (except DEM and land-water mask) to a fixed 1 km x 1 km grid. A grid cell assignment will be determined based on the latitude and longitude of each data point and an identification number (ID) corresponding to the selected cell will be stored in an auxiliary-ancillary table. The details of this mapping are in Section 3.3.

The DEM and land-water mask will be processed in the main production processing as part of geolocation. The DEM processing will yield terrain height, slope (TBD), and an indicator of rough or plateau terrain for each VIIRS pixel. A land-water-coastline indicator will be derived from the auxiliary-ancillary land-water mask. Each of these will be determined at the VIIRS pixel locations and stored in each SDR.

Re-gridding will provide the information needed for EDR algorithms to efficiently access auxiliary-ancillary data that is co-located with VIIRS pixels. Re-gridding will not perform any selection or interpolation among Auxiliary-ancillary data that may be available for different times. For example if an EDR algorithm is to process data observed at 0900Z the algorithm may require that there be an interpolation between NCEP model predictions at 0600Z and 1200Z. This interpolation will have to made within the EDR module. The re-gridding algorithm will provide the pointers that the EDR module will need to access the co-located data in both the 0600Z file and the 1200Z file that would be used in this interpolation.

Gridding of VIIRS SDRs, IPs, and EDRs will be a post-processing activity so as not to interfere with operational EDR production. In each case these gridded VIIRS data will be available to subsequent processing as the latest available data (i.e. current gridded data will not be used to process current data).

In preparation for the gridding process and to facilitate the match-up of auxiliary-ancillary data to the VIIRS pixels during EDR production the current VIIRS pixels will be mapped to the same fixed 1 km x 1 km grid that is used in auxiliary-ancillary data mapping. This VIIRS pixel mapping will be performed following the Earth location of VIIRS pixels (see *[V-2]*). A grid cell assignment will be determined based on the latitude and longitude of each pixel and an ID corresponding to the selected cell will be stored with each SDR. This cell ID will be carried into each IP and EDR that has to be gridded. The gridding algorithms will use this cell ID to bin and average the data. Software tools will be made available to the EDR algorithms to determine neighboring grid cell IDs in the event that a more sophisticated assignment of auxiliary-ancillary data is required for a particular EDR.

3.2 ALGORITHM INPUT

3.2.1 VIIRS Data

The following VIIRS data will be input to the VIIRS gridding algorithms:

- Calibrated Brightness Temperature SDR
- Remote Sensing Reflectance IP
- Sea Surface Temperature EDR
- Surface Temperature IP
- Surface Reflectance IP
- Surface Types IP
- Vegetation Index EDR
- Snow Cover/Depth EDR

3.2.2 Non-VIIRS Data

Auxiliary-ancillary data from a variety of sources and in a variety of formats will be re-gridded. These auxiliary-ancillary data are identified as part of the algorithm subsystem specification *[V-7]* and are further defined in the *[V-3]*. Table 1 summarizes the sources and types of auxiliary-ancillary data. This table is subject to change as the EDR algorithm requirements mature.

Table 1. Auxiliary-ancillary Data

Source	Type
ASTER	Spectral Library DEM ?
CMIS	Calibrated Microwave Brightness Temperature SDR (current) Cloud Liquid Water (latest) Cloud Ice Water Path (latest) Ice Age Sea Surface Winds (current ?) Surface Air Temperature (average over previous 12 hours)
CrIS	Surface Air Temperature (average over previous 12 hours) - Alternate Total Column Ozone (latest) – Fallback
Defense Mapping Agency (DMA)	Digital Bathymetric Database (non-coastal areas) Digital Elevation Model Land/Water Mask (vector shoreline)
EROS Data Center (EDC)	Geolocation Control Points (Landsat-7) Land/Water Mask
Fleet Numerical Meteorological Operational Center (FNMOC) or European Center for Medium Range Weather Forecasting (ECMWF)	Moisture Profile - Fallback Precipitable Water – Fallback Pressure Profile – Fallback Sea Surface Winds – Fallback Surface Air Temperature – Fallback Surface Pressure – Fallback Surface Temperature – Fallback Temperature Profile - Fallback
Goddard Institute for Space Science (GISS)	Aerosol Climatology (ocean)
MODIS	Aerosol Climatology (land) Geolocation Control Points Surface Types (at launch)
National Center for Environmental Prediction (NCEP) (analysis and model predictions)	Moisture Profile Precipitable Water Pressure Profile Ozone Concentration Sea Surface Winds Surface Air Temperature Surface Humidity Surface Pressure Surface Temperature Temperature Profile
National Data Buoy Center (NDBC)	Sea Surface Temperature (buoy locations)
National Ocean Service (NOS)	Digital Bathymetric Database (U.S. coastal waters)
National Weather Service (NWS)	Conventional Cloud Cover Observations (most recent)
OMPS	Total Column Ozone (latest)
Thuiller - SOLSPEC	Extraterrestrial Solar Irradiance

3.3 THEORETICAL DESCRIPTION OF EARTH GRIDDING

3.3.1 Grid Selection

The Earth gridding algorithm described in this section is intended to serve as an example. Additional development may modify this algorithm prior to CDR.

3.3.1.1 Considerations

VIIRS pixel size – select a grid size that is close to the spacing between the moderate resolution band pixels.

Number of cells – select a grid size that will result in a reasonable number of grid cells – consider storage and processing efficiency – convenient aggregation of cells should be considered.

Layout of cells – maintain a simple relationship between latitude and longitude and grid boundaries – avoid grid cells that straddle the Equator or a Pole due to physical (e.g. Coriolis force at Equator) and mathematical considerations.

3.3.1.2 Grid Definition

Approximately 1 km x 1 km is close to nadir pixel size of moderate resolution bands.

Cell boundaries parallel latitude circles to facilitate grid band assignment.

Each hemisphere is divided into an integral number of cell bands (i.e. cell boundary along Equator and Poles).

Each cell band is divided into an integral number of cells (i.e number of cell within a cell band will be a function of latitude) to facilitate grid ID assignment.

3.3.1.3 Grid Characteristics

The Earth model will have 20014 cell bands (10007 in each hemisphere).

Cell bands 1 & 20014 (i.e. northern most and southern most) contain 3 cells each.

Cell bands 10007 & 10008 (i.e. adjacent to Equator) contain 40032 cells each.

Number of cells within a cell band is a function of the cosine of the central latitude for that band.

Table will define grid so that grid cell ID can be determined by using pixel latitude and longitude.

3.3.2 Grid Cell Identification

Each grid cell is assigned a number.

Cell numbering starts at 1 for the most northwest cell and then increments eastward to the end of a cell band then continues with the western most cell in the next cell band moving south; this continues to the last (i.e. southeastern most) cell, which will be cell number 510,900,000 (TBR).

29 bits are required for the cell number (assuming the there will be no more than 536,870,911 cells in the grid).

Here the western most cell is defined as that which has its western boundary along the –180 deg. meridian.

A static Grid Definition table will be constructed with one row per cell band starting with the northern most and ending with the southern most; columns will include the northern latitude limit, the southern latitude limits, the cell number of the western most cell, and the number of cells in the band.

3.3.3 Mapping VIIRS SDR Pixels

Following Earth location a cell number will be assigned to each VIIRS pixel. A single cell number will be assigned to each moderate resolution pixel and each imagery resolution pixel.

The assignment will use the static look-up table that describes the grid (see Section 3.3.2, Grid Cell Identification).

A 3 bit code will be set to indicate if the pixel location is near a cell boundary as follows:

000 = not near a cell boundary

001 = near the northern cell boundary

010 = near the southern cell boundary

011 = near the western cell boundary

100 = near the eastern cell boundary

101 = near the corner of a cell and North of center

111 = near the corner of a cell and South of center

What is considered near is TBD; it could be set so that only a pixel that is centered in the grid cell would have a code=000.

The combination of the 3 bit code and the 29 bit grid cell number will be referred to as a Grid Reference Number (GRN).

The GRN will be stored as an unsigned 2 byte integer in each SDR along with pixel latitude, longitude, etc.

3.3.4 Mapping Auxiliary-Ancillary Data

3.3.4.1 Table Initialization

An Auxiliary-Ancillary Mapping Table will be created with one row per grid cell number arranged in sequence from grid cell 1 to grid cell 510,900,000 (TBR).

There will be a column for each type of auxiliary-ancillary data.

In cases where a data type has multiple resolutions then separate columns will be created for each.

Each column in this table will be populated with the byte offset to the data that coincides with the grid cell – the byte offset will correspond to the start of the auxiliary-ancillary data structure.

Auxiliary-ancillary file names and data formats will be linked to each data type (i.e. each column).

3.3.4.2 Table Update

The Auxiliary-Ancillary Mapping Table will be updated whenever new auxiliary-ancillary data types are added to or removed from the VIIRS processing architecture or when new auxiliary-ancillary data are received that contain data for locations that are different than the locations in previously received auxiliary-ancillary data of the same type.

Table updates will likely not be required for the byte offsets to gridded auxiliary-ancillary data – this would only be necessary if input file formats were changed.

3.3.5 Auxiliary-Ancillary Data Access in EDR Modules

3.3.5.1 General Case

In general EDR algorithms will have direct access to the auxiliary-ancillary data that a pixel retrieval needs by using the cell number stored as the GRN in each input SDR.

The cell number identifies the row in the Auxiliary-Ancillary Mapping Table to read to retrieve the byte offset in the auxiliary-ancillary file of interest.

3.3.5.2 EDR Algorithm Specific Cases

Some EDR algorithms may require neighboring grid cell auxiliary-ancillary data.

This may be the case when no auxiliary-ancillary data are available for the grid cell that corresponds to the VIIRS pixel.

It may be desirable to average auxiliary-ancillary data from neighboring grid cells with the auxiliary-ancillary data from the the grid cell that corresponds to the VIIRS pixel.

The latter may be especially true if the VIIRS pixel location falls near a grid cell boundary as indicated by the code that is stored with each GRN (see Section 3.3.3, Mapping VIIRS SDR Pixels).

There is sufficient information in the Grid Definition Table, the Auxiliary-Ancillary Mapping Table, and the GRN to determine neighboring data and to efficiently ingest them into the EDR algorithms.

Common software tools can be used by each EDR algorithm as needed to bring in neighboring auxiliary-ancillary data.

3.3.6 Generation of Gridded VIIRS SDRs, IPs, and EDRs

3.3.6.1 General Approach

The concepts used for re-gridding are extensible to the gridding process.

The gridded products will be tables that have one row assigned for each grid cell arranged from grid cell number 1 to grid cell number 510,900,000 (TBR).

For latest available gridded products there will be one table in which each row's values will be the latest available data assigned to that grid cell (i.e. as new data become available they are used to replace values in the table).

For those gridded products that are averages over some time period (daily, weekly, monthly, and quarterly) a new table is created every time a new orbit of data becomes available (here an orbit is defined as all data downlinked at the same time) – at some pre-defined frequency the tables for the specified time period are combined using interpolation and averaging techniques that are product specific to create a new table.

3.3.6.2 Product Specific Algorithms

Details regarding the definition and the rules for data selection, interpolation, and averaging are listed according to gridded product.

Gridded Daily Surface Reflectance IP

The Gridded Daily Surface Reflectance (GDSR) Intermediate Product (IP) is required for the retrieval of the Surface Albedo EDR over dark surfaces, including most vegetation and water. For these surfaces, pixel-level retrievals are based on an extension of the MODIS albedo algorithm, described in great detail in Lucht *et al.* (2000). The modification of this algorithm for VIIRS purposes, hereafter referred to as the Surface Albedo Sub-Algorithm 1 (SASA1) is presented in *[Y2398]*.

SASA1 operates on a running window of sixteen days worth of daily surface reflectance data, to allow the inversion of a system of equations yielding the necessary coefficients for producing black sky and white sky albedo estimates. Since a temporal series of surface reflectances is required, the data must be mapped to a common grid. The GDSR will therefore be a three-dimensional array with the structure indicated in Table 2.

Table 2. Gridded Daily Surface Reflectance (GDSR) IP array structure.

Dimension	Elements
Temporal	(Current Day) thru (Current Day – 16)
Global Grid (Spatial)	(Grid Cell 1) thru (Grid Cell N)
Parameter	Reflectance* in VIIRS Bands M1, M2, M3, M4, I1**, I2**, M8, I3**, M11; Solar zenith; View zenith; Relative azimuth

*Grid cells contaminated by cloud, heavy aerosol, etc. contain negative fill values

**Imagery bands aggregated 2x2 before being incorporated into GDSR

At the time of its use, the GDSR IP will consist of data from the sixteen days prior to the current day, plus a partially completed grid for the current day. Once the Surface Reflectance IP has been retrieved and archived for a given granule, it will be resampled via cubic convolution onto the global 1-km grid for the current day. The solar/viewing geometry must also be resampled and retained in this manner. When the grid for the current day has been completed, the cell values for the GDSR IP will be shifted by one element in the temporal dimension, and the cells corresponding to the current day will once again be blank.

Gridded Weekly Surface Reflectance IP

The Gridded Weekly Surface Reflectance (GWSR) IP is required by the Cloud Effective Particle Size and Cloud Optical Thickness EDRs. For more detail on the algorithms and usage of this product in the Cloud Module, the reader is directed to *[Y2393]*.

The structure of the GWSR IP is shown in Table 3.

Table 3. Gridded Weekly Surface Reflectance (GWSR) IP array structure.

Dimension	Elements
Temporal	(Composite), (Current Day) thru (Current Day – 8)
Global Grid (Spatial)	(Grid Cell 1) thru (Grid Cell N)
Parameter	Composited, Nadir-adjusted Reflectance* in VIIRS Bands M1, M2, M3, M4, I1**, I2**, M8, I3**, M11

*Grid cells contaminated by cloud, heavy aerosol, etc. contain negative fill values

**Imagery bands aggregated 2x2 before being incorporated into GWSR

The GWSR IP is a running, eight-day, nadir-adjusted composite. Once Surface Reflectance has been retrieved and archived for a given granule, it will be resampled via cubic convolution onto the global 1-km grid for the current day. This process can be merged with the same process for generating the GDSR IP, so that the GDSR IP itself can be used as the storage mechanism for the non-nadir-adjusted data. Once data are regridded for a given granule, they must be converted to nadir-adjusted values to remove the bi-directional reflectance distribution function (BRDF) signal from the composite. This is done using a BRDF shape associated with the most recent value of the Quarterly Surface Types IP on the 1-km grid. A simple conversion factor is applied to the resampled surface reflectance data to arrive at the nadir-adjusted value. This nadir-adjusted value is then placed into the current day grid of the GWSR IP. Once the global grid for the current day is complete, the cell values for the GDSR IP will be shifted by one element in the temporal dimension, and the cells corresponding to the current day will once again be blank. Also at this time, the composite grid in the temporal dimension is updated. Each cell in this grid is filled with the mean of all non-cloud cell values from the eight full days of previously computed reflectances. The composite grid is the product used by the Cloud Module.

Gridded Monthly Surface Reflectance IP

The Gridded Monthly Surface Reflectance IP (GMSR) is required for use by the Surface Type EDR, which generates metrics from the IP as inputs to a decision tree classification algorithm. For further details on the Surface Type algorithm, the reader is directed to *[Y2402]*.

The structure of the GMSR IP is shown in Table 4.

Table 1. Gridded Monthly Surface Reflectance (GMSR) IP array structure.

Dimension	Elements
Temporal	(Current Month) thru (Current Month – 2), (Current Week) thru (Current Week – 3)
Global Grid (Spatial)	(Grid Cell 1) thru (Grid Cell N)
Parameter	Composited, Nadir-adjusted Reflectance* in VIIRS Bands M1, M2, M3, M4, I1**, I2**, M8, I3**, M11

*Grid cells contaminated by cloud, heavy aerosol, etc. contain negative fill values

**Imagery bands aggregated 2x2 before being incorporated into GMSR

A week is defined to be eight days here

The GMSR IP is a non-running, monthly composite of nadir adjusted reflectances. To minimize storage requirements and computational load, the GMSR IP will be constructed from the GWSR IP. Every eight days—except for the final period within a month, which will consist of between four and seven days—the current composiste grid for the GWSR IP will be copied into the appropriate array within the GMSR IP. At the conclusion of each month, the four weekly arrays within the GMSR IP will be averaged into one of the three monthly arrays within the GMSR IP. Every three months, the three monthly arrays in the GMSR IP are used to generate the Quarterly Surface Types IP for Surface Type EDR processing. The processing then starts anew, over-writing all fields within the GMSR IP.

Monthly Non-snow Surface Reflectance IP

The Monthly Non-snow Surface Reflectance IP (MNSR) is required for use by the Snow Cover/Depth EDR, which must characterize the background in a given pixel to estimate the snow fraction using spectral mixture analysis. For further details on the snow fraction algorithm, the reader is directed to *[Y2401]*.

The structure of the MNSR IP is shown in Table 5.

Table 5. Monthly Non-snow Surface Reflectance (MNSR) IP array structure.

Dimension	Elements
Temporal	(Composite), (Current Day) thru (Current Day – 32)
Global Grid (Spatial)	(Grid Cell 1) thru (Grid Cell N)
Parameter	Composited Spectral Albedo* in VIIRS Bands M1, M2, M3, M4, M5, M7, M8,M10, M11

*Grid cells contaminated by cloud, heavy aerosol, snow, etc. contain negative fill values

A week is defined to be eight days here

The MNSR IP is a running, monthly composite of narrowband spectral albedo. Once the Surface Reflectance IP has been retrieved and archived for a given granule, it will be resampled via cubic convolution onto the global 1-km grid for the current day. Pixels categorized as snow by the Snow Cover/Depth EDR will not be used in the interpolation. Once data are regridded for a given granule, they must be converted to spectral albedo to remove the bi-directional reflectance distribution function (BRDF) signal from the composite. This is done using a BRDF shape associated with the most recent value of the Quarterly Surface Types IP on the 1-km grid. A simple conversion factor is applied to the resampled surface reflectance data to arrive at the spectral albedo. At the conclusion of each month, the daily arrays within the MNSR IP will be averaged into the composite grid within the MNSR IP. This composite grid is used by the Snow/Cover Depth EDR algorithm.

Gridded Surface Albedo IP

The Gridded Surface Albedo (GSA) IP is required for the retrieval of the Surface Albedo EDR over dark surfaces, including most vegetation and water. For these surfaces, pixel-level retrievals are based on an extension of the MODIS albedo algorithm, described in great detail in Lucht *et al.* (2000). The modification of this algorithm for VIIRS purposes, hereafter referred to as the Surface Albedo Sub-Algorithm 1 (SASA1) is presented in *[Y2398]*.

SASA1 operates on a running window of sixteen days worth of daily surface reflectance data, to allow the inversion of a system of equations yielding the necessary coefficients for producing black sky and white sky albedo estimates. Since a temporal series of surface reflectances is required, the data must be mapped to a common grid.

The structure of the GSA IP is shown in Table 6.

Table 6. Gridded Surface Albedo (GSA) IP array structure.

Dimension	Elements
Global Grid (Spatial)	(Grid Cell 1) thru (Grid Cell N)
Parameter	Black Sky Albedo*, White Sky Albedo*, Kernel Weights and Coefficients* (exact structure to be refined in V5 of this ATBD)

*Grid cells from too few observations contain negative fill values

The GSA IP is a global 1-km grid of albedo computation parameters based on a running set of sixteen days worth of surface reflectance data delivered via the GDSR IP. Each day, the sixteen full days of surface reflectances within the GDSR IP are used to perform an inversion that delivers a set of coefficients for computing the black sky and white sky albedo in a given grid cell. These parameters are then ingested and interpolated by SASA1 for pixel-level retrievals of the Surface Albedo EDR for dark surfaces. The GSA IP also includes the derived coefficients themselves, allowing the end user more flexibility for performing further calculations. For a description of the inversion algorithm and more detail on how the GSA IP interacts with the Surface Albedo EDR, the reader is directed to the Surface Albedo ATBD *[Y2398]*.

Gridded Monthly Vegetation Index IP

The Gridded Monthly Vegetation Index (GMVI) IP is required for use by the Surface Type EDR, which generates metrics from the IP as inputs to a decision tree classification algorithm. For further details on the Surface Type algorithm, the reader is directed to *[Y2402]*.

The structure of the GMVI IP is shown in Table 7.

Table 7. Gridded Monthly Vegetation Index (GMVI) IP array structure.

Dimension	Elements
Temporal	(Current Month) thru (Current Month – 2), (Current Week) thru (Current Week – 3)
Global Grid (Spatial)	(Grid Cell 1) thru (Grid Cell N)
Parameter	Composited Normalized Difference Vegetation Index (NDVI)*

*Grid cells contaminated by cloud, heavy aerosol, etc. contain negative fill values

**Imagery bands aggregated 2x2 before being incorporated into GMVI

A week is defined to be eight days here

The GMVI IP is a non-running, monthly composite of the Normalized Difference Vegetation Index (NDVI). The physics behind the NDVI are described in *[Y2400]*. To minimize storage requirements and computational load, the GMVI IP will be produced directly from the GWSR IP. At the conclusion of each week, the red (aggregated I1) and near infrared (aggregated I2) reflectances in the currently computed weekly grid from the GWSR IP will be used to generate the values in the corresponding weekly grid of the GMVI IP. At the conclusion of each month, the four weekly arrays within the GMVI IP will be averaged into one of the three monthly arrays within the GMVI IP. Every three months, the three monthly arrays in the GMVI IP are used to generate the Quarterly Surface Types IP for Surface Type EDR processing. The processing then starts anew, over-writing all fields within the GMVI IP.

Gridded Monthly Brightness Temperature IP

The Gridded Monthly Brightness Temperature (GMBT) IP is required for use by the Surface Type EDR, which generates metrics from the IP as inputs to a decision tree classification algorithm. For further details on the Surface Type algorithm, the reader is directed to *[Y2402]*.

The structure of the GMBT IP is shown in Table 8.

Table 8. Gridded Monthly Brightness Temperature (GMBT) IP array structure.

Dimension	Elements
Temporal	(Current Month) thru (Current Month – 2), (Current Day) thru (First Day of Current Month)
Global Grid (Spatial)	(Grid Cell 1) thru (Grid Cell N)
Parameter	Composited Brightness Temperature* in VIIRS Bands I4**, M12, M13, M14, M15, I5**, and M16

*Grid cells contaminated by cloud, heavy aerosol, etc. contain negative fill values

**Imagery bands aggregated 2x2 before being incorporated into GMBT

The GMBT IP is a non-running, monthly composite of brightness temperatures. Once the Calibrated TOA Brightness Temperatures SDR has been retrieved and archived for a given granule, it will be resampled via cubic convolution onto the global 1-km grid for the current day. At the conclusion of each month, the non-cloud entries within the daily arrays in the GMBT IP will be averaged into one of the three monthly arrays within the GMBT IP. Every three months, the three monthly arrays in the GMBT IP are used to generate the Quarterly Surface Types IP for Surface Type EDR processing. The processing then starts anew, over-writing all fields within the GMBT IP.

Gridded Quarterly Surface Types IP

The generation of the Gridded Quarterly Surface Types IP is described in *[Y2402]*.

Gridded Vegetation Index Secondary Products

The generation of the gridded Vegetation Index Secondary Products, including the Weekly Vegetation Index (WVI), Net Photosynthesis (PSN), and Net Primary Productivity (NPP) is described in *[Y2400]*.

Latest Gridded Remote Sensing Reflectance

Latest Gridded Sea Surface Temperature

Latest Gridded Surface Air Temperature

3.4 PRACTICAL CONSIDERATIONS

3.4.1 Numerical Computation Considerations

Paragraph SRDV3.2.1.5.4-1 of the VIIRS SRD states the following:

> "*The scientific SDR and EDR algorithms delivered by the VIIRS contractor shall be convertible into operational code that is compatible with a 20 minute maximum processing time at either the DoD Centrals or DoD field terminals for the conversion of all pertinent RDRs into all required EDRs for the site or terminal, including those based wholly or in part on data from other sensor suites*."

The algorithms for matching auxiliary-ancillary data to the VIIRS pixels are straightforward and will have a minimum impact on VIIRS processing resources. The impact of the gridding of VIIRS products will be determined by the definitions an rules that are to be included in Section 3.3.6.2, Product Specific Algorithms.

3.4.2 Programming and Procedural Considerations

It is expected that some of the re-gridding and gridding requirements are not known at the present time or may change in the future. Therefore the VIIRS software architecture should be flexible enough to accommodate modifications if and when needed.

Details of the software for re-gridding and gridding are presented in the VIIRS Context Software Architecture *[V-5]* and the VIIRS Earth Gridding Software Architecture *[V-6]*, documents. The Earth Gridding units are parts of the Build SDR module, which is discussed in the VIIRS Algorithm Subsystem Specification *[V-7]*.

4.0 REFERENCES

Kilpatrick, K.A., G.P. Podesta, and R. Evans. Overview of the NOAA/NASA AVHRR Pathfinder Algorithm for Sea Surface Temperature and Associated Matchup Database, University of Miami.

Lucht, W., C.B. Schaaf, and A.H. Strahler. An Algorithm for the retrieval of albedo from space using semiempirical BRDF models, IEEE Trans. Geosci., Remote Sens., 38, 977-998, 2000.